Phase I Project Summary

Firm: Latitude Engineering LLC

Contract Number: NNX13CP29P

Project Title: In-Situ Aerial Sampler for Advanced Guided Dropsonde

Identification and Significance of Innovation:

The proposed innovation is a low-cost, retrievable and reusable, autonomously guided dropsonde capable of deploying from a host aircraft and performing in-situ atmospheric measurements. We have decided to name this platform the NavSonde−an autonomously navigable sonde-glider.

Small scale particulate sampling equipment for airborne missions is not commercially available. Even for full scale manned systems, many research programs develop their own collection and sensor systems. A small form factor unmanned aerial sampling system, such as the NavSonde, that is capable of being deployed from a host aircraft at high altitudes and autonomously guided to regions of interest will offer NASA atmospheric scientists an innovative research tool−particularly for those seeking unprecedented access to high altitude atmospheric sampling to monitor events that may be deemed too dangerous for manned aircraft.

The ability to retrieve high altitude particulate and gas samples from volcanic plumes is a crucial task in assessing and evaluating the danger these plumes pose to aviation traffic. The economic impact volcanic eruptions may have on travel, commerce, and supply logistics is substantial as recently shown by the 2010 Eyjafjallajökull eruption in Iceland and the 2011 Puyehue eruption in Chile. Both events canceled hundreds of flights for weeks, leaving thousands of travelers stranded. While satellites provide valuable data to inform prediction models, they lack the ability to accurately estimate particle size and to determine how particles track with gases present in the plume. Collecting particle and gas samples is important to validate plume models and to determine the safety of flight for air traffic routes that may be affected by volcanic activity. Unmanned autonomous aerial vehicles (UAVs) hold great promise in performing in-situ sampling to assist with these efforts.

Advanced guided dropsondes, and the NavSonde in particular, will have a significant logistic advantage as they will be regulated by the FAA as dropsondes and not UAVs. This will open up many research opportunities currently denied to most commercial UAVs and may make advanced guided dropsondes the platform of choice for conducting low-cost airborne atmospheric research. Autonomously guided dropsondes such as the NavSonde have several advantages over current dropsondes−the main ones being their ability to fly to regions of interest and to perform pre-programmed actions at specified locations and/or altitudes (e.g. gather particulate samples).

Technical Objectives, Work Plan, and Technical Accomplishments:

The technical objectives of this Phase I effort were the following:

(1) Determine if the current MIST-sized AGD provides a technically feasible platform for an aerial particulate sampler (assess aerodynamic performance as well as integration issues due to its very small size).
(2) If the current MIST-sized AGD platform is not practical to host a particulate sampler, then upsize the current AGD design to the AVAPS-sized sonde.
(3) Design and test the particulate sampler and its host advanced guided dropsonde.

The Phase I work plan consisted of the following major tasks:

- I. Investigate and determine if a deployable vertical stabilizer is practical and economical to implement in the current AGD.
- II. Design and integrate a prototype sampling system into the current AGD.
- III. If the engineering objectives of tasks I and II cannot be practically met within the current AGD form factor, then we will proceed down the path of designing a comparably functional AVAPS sized system.
- IV. Development of the AVAPS sized AGD (NavSonde) with integrated particulate sampler.
- V. At least two flight tests will be required to validate the aerodynamic performance of the modified AGD and/or the AVAPS AGD. The effectiveness of the airborne in-situ sampler will also be evaluated.
- VI. The test results from the flight tests will be made into reports available to NASA. Engineering recommendations for further refinements will be presented.

Within the context of the technical objectives, the key goals of this Phase I proposal are:

(1) Demonstrate the capability of the AGD to be released from a host manned aircraft and achieve stable flight.
(2) Collect an atmospheric particulate sample from a pre-programmed altitude and location.
(3) Deliver the protected sample to a pre-programmed recovery area.

The technical accomplishments of this Phase I effort were the following:

(1) We developed an aerial sampler for an autonomously guided dropsonde called the NavSonde. Sized for the AVAPS sonde tube deployment system, the NavSonde is a low-cost, retrievable and reusable, autonomously guided dropsonde capable of deploying from a host aircraft and performing in-situ atmospheric measurements. Specifically, we achieved the following for the prototype airframe and sampler:
    - a. Developed three NavSonde airframe designs, including articulating wings and control surfaces. One airframe was designed to house the sampler, the second was designed the house a camera in lieu of the sampler, and the third housed a camera and a small sampler.
    - b. Prototype multi-stage particulate sampler design, sized to fit the NavSonde
    - c. Integrated the Piccolo Nano autopilot into the NavSonde including preliminary AVL model and gain configurations
    - d. Prototype launch/drop tube for use on manned aircraft

(2) In Phase I, we demonstrated that the prototype NavSonde is capable of being released from a manned host aircraft, articulate its wings into a flying configuration, recover from an unstable attitude, and autonomously glide to a pre-determined waypoint where it can be retrieved by a ground crew. Two test flights of the NavSonde were conducted. While a launch mishap caused the first NavSonde to crash, the second test flight was successful. Both NavSondes were recovered from both test flights and in both cases, the main part of the fuselage that would have housed a sampler was intact, indicating that the sampler unit would have survived.

(3) While we fell short on time and were not able to demonstrate the functionality of the aerial sampler we designed for this effort, we did demonstrate the robustness of the NavSonde’s design and construction as well as the survivability of the NavSonde’s payload (e.g. sampler).

NASA Application(s):

The relevance of the work performed for this Phase I SBIR falls under the NASA 9.1.3 Science subtopics S1.08 Airborne Measurement Systems and S3.05 Unmanned Aircraft and Sounding Rocket Technologies.

Methods for obtaining high resolution atmospheric data have become an increasingly important and relevant engineering challenge. Sampling of atmospheric phenomena is an important component for research and modeling. This data has a variety of applications from monitoring climate change to disaster response. The capability to safely collect direct samples from hazardous atmospheric phenomena has been technically elusive, particularly for those events occurring at high altitudes. Unmanned Aerial Vehicles (UAVs) hold great potential for conducting this type of atmospheric research. Instruments that can be easily and cost-effectively integrated onboard UAVs will augment NASA's capability to conduct innovative atmospheric research particularly in situations deemed too dangerous or risky for manned aircraft. For volcanic eruptions, retrieving ash samples from actual airborne plumes is a rare event. The ability to collect and analyze ash from plumes would significantly benefit hazard prediction for aviation safety. The recent 2010 eruption of Eyjafjallajökull volcano in Iceland and the 2011 Puyehue eruption in Chile highlight this need. Ash samples taken directly from the plumes would have showed composition and size distribution of hazardous particulates, greatly improving the ability to model and predict the location and extent of the aviation hazard. Particle and aerosol collection systems suitable for small class UAVs and dropsondes are not readily available and in many cases, researchers develop their own samplers and sensors for atmospheric research. A particulate sampling system that can be used on a guided dropsonde is a key technology to be developed.

Dropsondes have been instrumental in the research of storms, hurricanes, and other atmospheric events such as the increasing intensity of dust storms. The utility of the dropsonde in studying these events can be enhanced significantly with the addition of guidance systems that can increase loiter time or enable movement toward areas of interest. Retrieving samples moves this application a step further, particularly in studying precursor events. Guided dropsondes have significant implications to advance research in nearly all scientific disciplines requiring in-situ atmospheric measurements. Compared to conventional free-fall dropsondes that rely on parachutes, guided dropsondes offer speed controlled descents combined with the ability to loiter. These unique abilities can potentially yield time averaged data for a particular region—a feature not currently available with existing dropsonde technology. The guided dropsonde's ability to move to targeted areas of interest gains sensors an unprecedented level of access to extreme areas and events.

The work Latitude Engineering performed under the current Phase I effort made significant progress towards this meeting these needs. The results of the Phase I have showed us that the NavSonde is a viable autonomous guided dropsonde platform. Combined with its aerial sampler, we are confident that the NavSonde will prove itself to be an innovative atmospheric research tool.

Non-NASA Commercial Application(s):

News of the potential of guided dropsonde technology development has been well received within key US UAS science programs and numerous organizations look forward to its commercial availability. In addition to NASA, potential end-customers in NOAA and DOE have expressed interest in the project.

The main application of the NavSonde and its particulate sampler is to gather physical data so that various international monitoring agencies can accurately assess the impact volcanic ash plumes can have on commercial aviation safety. We anticipate that the main users of the NavSonde will be governments and other regulatory agencies concerned with monitoring air traffic routes.

More generically, as a guided dropsonde platform, the NavSonde can be outfitted with other kids of meteorological sensors and scientific payloads. This will make it appealing as a low-cost, small scale airborne platform to many potential end users.

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